CHAPTER 16. IONIZED AND NON-IONIZED RADIATION MEASUREMENTS

1600. PURPOSE. This chapter specifies the procedures and considerations for ionized and non-ionized radiation measurements to be made by the FMO.

1601. GENERAL. Order 3910.3 assigns specific responsibility in the area of radiation safety. The FMO is responsible for the actual definitive measurements of radiation levels. Detailed measurement procedures are contained in the Radiation Hazard Course book.

a. ASR is the single point-of-contact within the FAA for performing radiation hazard measurements, both ionizing and non-ionizing.

b. FAA field activities shall contact their regional FMO or ASR to address any consideration of radiation hazard measurements.

c. ASR will be responsible for ensuring the ability to perform radiation measurements in a timely manner, to include training of ASR engineers and regional FMO's.

d. Only ASR staff, FMO's, or technical support provided or supported by ASR, shall make radiation hazard measurements on FAA equipment.

e. FAA Engineering and Environmental Safety Division (ANS-500) has overall program management responsibility for environmental hazards, including radiation hazards.

f. ANS-500 is the budget advocate for funding radiation monitoring and measurement equipment.

g. On an infrequent basis, it may be necessary for the FMO to perform a radar antenna pattern measurement by solar means in order to advise on radar antenna tilt angle to resolve RADHAZ issues. Refer to the appendix for detailed instruction on how to perform these measurements.

h. Each FMO has been supplied with a series of instruments to accomplish this task.

(1) FSM's for low level RF (non-ionized) radiation in the 30 MHz-10 GHz range.

(2) Narda Model 8316B for high power non-ionized RF radiation with probes for LF-SHF ranges.

(3) Victoreen Model 440RF for ionized radiation. It is shielded for use in high RF fields.

(4) Spectrum Analyzers also may be used for non-ionized measurements < 1 mW/cm^2.

1602. IMPORTANCE OF MEASUREMENTS. The importance of this function cannot be overemphasized. The results of the FMO's measurements can affect the safety, health, and in extreme cases, the life of a person who must work or be in the area being measured. The latest edition of ORDER 3910.3 MUST BE UNDERSTOOD BY THE FMO AND STAFF. The order is very detailed in its description of the two basic kinds of radiation and the limits in which the human body can safely exist.

1603. FMO PARTICIPATION LIMITATION. Only measurements of level are made by the FMO. The results of the measurements are reported to the Manager of the Environmental Compliance and Employee Safety Branch (ANS-510) and ANS-500 for further coordination with other offices, required medical interpretation and follow-on actions.

1604. IMPORTANCE OF ACCURACY. The measurements made by the FMO are only as good as the calibration of the instrumentation used and the accuracy, thoroughness, and professionalism of the FMO or staff engineer making the measurements.

1605. INSTRUMENT CALIBRATION. The calibration of instrumentation is the responsibility of the FMO. All instruments involved shall be calibrated at least annually, or more frequently if the manufacturer recommends. In the case of ionized radiation instrumentation (Victoreen 440RF), the built-in calibrator will be used to verify approximate calibration immediately before any measurements of record are made. If the built-in calibrator leads to readings greater or less than 5 percent of the specified, the instrument will not be used for measurement until it has been recalibrated by the manufacturer or a certified field calibration station.

1606. AVAILABILITY. The instruments shall be available at all times, and in condition for immediate use. This means all required batteries are fresh, and internal calibration checks have been made at periodic intervals. When ANS-510, Program Office, or Flight Surgeon requests a measurement, the FMO response will be commensurate with the urgency of that request. Particularly in the case of a suspected case of employee, general public or visitor radiation, the measurements must be made as quickly as possible and the results given verbally to those officials listed in paragraph 1603, even before the written report is completed. ASR also shall be advised of results by telephone or fax.

1607. RAMIFICATIONS. The FMO is charged by directive to be the responsible person in the region to make all radiation hazard (RADHAZ) measurements. This is not a transferrable responsibility. If the FMO cannot make the measurements for any reason, ASR must be contacted immediately for assistance.

a. Any measurement made as a result of a complaint by any person, FAA or not, of radiation injury from FAA equipment is likely to be used by the appropriate authority as a basis for liability assessment.

b. The person making the measurement may be required to appear as a Federal Government witness at an administrative hearing or trial litigation and may be required to prove expertise based on knowledge and experience in making measurements.

c. It is imperative that the FMO be thoroughly familiar with the equipment used (most likely the Narda 8316B or Victoreen 440 RF). The FMO must be knowledgeable of the manufacturer's specifications on accuracy, calibration requirements, procedures for use and overall analysis procedures.

d. Except under extenuating circumstances, the FMO's RADHAZ equipment shall not be loaned outside the FMO.

e. The FMO must assure that all personnel who would use the instruments are thoroughly trained in the use of RADHAZ measurement equipment. The FAA will provide the necessary training. It is highly desirable that regular measurements on NAS equipment, e.g., long range radars, be done as a proficiency training requirement.

1608. MEASUREMENT PHILOSOPHY.

a. Paragraphs 1601 and 1603 specify that only the FMO office makes the official radiation measurements for the agency. The FMO is not authorized to make any judgment as to any health hazard or lack thereof. When measurements have been completed, they shall be reported as required, followed by a written report signed by the person actually making the measurements.

b. Order 3910.3 specifies that the measurements will be made with the full cooperation and assistance of maintenance and management personnel responsible for the equipment concerned. It is likely that those persons will be watching as the measurements are being made, to see whether the indications might show a hazardous condition. The FMO should be fully open to those persons responsible who watch as to the numeric values obtained. But the FMO or engineer making the measurements shall make no assumptions as to health hazards pro or con. If pressed for comment, the FMO will refer the inquirer to Order 3910.3, or to the Regional Flight Surgeon.

1609. MEASUREMENT CONSIDERATIONS. There are four instruments listed in paragraph 1601. Use an FSM, EMI receiver or SA for measuring low level microwave; the Narda for high power, mostly radar and microwave; and the Victoreen for ionized radiation, mostly X-ray, around high power equipment such as radar and TACAN. These instruments have been supplied to all regional FMO's. Additional or updated equipment will be supplied from time to time.

a. L/MF, HF, and VHF radiation will be required infrequently, except for scope emissions. Down to 30 MHz, the Eaton NM-37/57 is used for low level radiation, the Narda for high level.

b. The Narda's lowest practical reading is 1 milliwatt per square centimeter (mW/cm^2). Below that level, calibrated field strength instruments must be used for non-ionized measurements.

c. In non-ionized radiation, it is the AVERAGE power that must be found.

(1) Where a radar is rotating, it will be nearly impossible to receive an average power density level above the permissible exposure limit (PEL). Considering the width of the radar beam and the antenna azimuth rate, a person at a fixed point (unless it was in the immediate vicinity of the radar antenna sail) would receive only that percentage of power equal to the beam width divided by 360, per unit time. For instance, a 2° beam width rotating radar would radiate any given point only 2/360 or 0.55 percent of the power measured at the same point under radar fixed illumination. There is substantial radiation from the side lobes, normally -30 dB or so down from the main lobe peak.

(a) In the near field, antenna lobes are not well defined and calculations based on them cannot be totally relied upon. This point is very significant and should be brought out in any report as a result of measurements of a rotating radar.

(b) Use of an FSM for RADHAZ measurements must be considered only when the level is < 1 mW/cm^2. Greater levels may not be read accurately by the FSM due to the limit of the shielding of the FSM, or front end overload. In those cases where an FSM is used, the "peak hold" mode must be used so that the meter ballistics can be negated by the time hold. Conversion from dB/µv to mW/cm^2 must be accomplished after the FSM measurement is completed. For this procedure, refer to the RFI manual described in paragraph 1400.

(2) Persons uninformed about radiation may become overly concerned when they think they might be in a hazardous field. In this regard, the FMO must never rely upon inexpensive non-ionized "radiation detectors" which can be bought for only a few dollars. Not only are they without any calibration, they usually are designed to operate on peak power, rather than average. About the only thing that can be said for them, other than they frighten people, is that they usually are very over-sensitive, so that persons using them probably are far safer than they think.

(3) Home-made detectors can be a problem. In one instance, an FAA radar site employee claimed radiation injury from the radar. The employee had constructed a standard Yagi antenna, resonant to the radar frequency, and placed a small NE-2 neon bulb at the feed point. The bulb lit nearly anywhere on the transmitter floor level, whenever the Yagi was pointed upward. Even considering the gain of the constructed Yagi, it took considerable time and effort to show that the bulb was lighting from peak power. Actual calibrated measurements throughout the area showed less than 5 percent of PEL.

(4) Diversity of opinion concerning radiation dangers must not in any way distract the FMO from absolutely assuring every reported or suspected radiation hazard is thoroughly investigated and reported as required in Order 3910.3.

1610. MEASUREMENT PROCEDURES. Whether ionized or non-ionized, measurement of radiation is really just a form of field strength measurement, with which the FMO is very familiar in spectrum surveillance work. The difference is that in an area where possible health hazard from ionized radiation is being investigated, measurement must be approached much more carefully than the usual field strength measurement.

1611. IONIZED RADIATION MEASUREMENT PROCEDURES.

a. Ionized radiation deals with those extremely short wavelengths in the X-ray, alpha, beta and gamma ray bands. The instrument supplied to all FMO's is the Victoreen 440RF, the "RF" portion of the model number indicating it is shielded for operation in even very high RF fields. Other instruments, especially the CDV-700, must not be used without consulting ASR. While it is accurate for radiation purposes, the CDV-700 is not accurate in the presence of high RF fields as are encountered in FAA facilities.

b. Calibration and use.

(1) The very first action the measuring engineer must take is to thoroughly read the instruction book which comes with each instrument. Complete familiarity with its provisions is mandatory before every measurement.

(2) Next, battery level shall be checked by the integral meter. If not at an operating level, batteries must be replaced before the meter is used for measurement.

(3) Instrument self-calibration is accomplished by bringing the built-in calibration source into the specified area of the sensing cylinder. Measurements may proceed only if the self-calibration test is satisfactory.

(4) Turn on the instrument to its most sensitive level. The circuit should be zeroed, if necessary. Zeroing should be checked at all scale levels.

(5) The meter should read nearly zero except for an occasional flick at the lowest scale level, caused by casual neutrons or gamma rays passing through the sensor. If the meter reads considerably upscale, the reason for that level reading shall be determined before any further readings are made. It is important that the instrument is first turned on well outside any expected measurable radiation area.

(6) Once the meter is found to be operating normally, the area which is to be measured will be entered slowly and carefully. Watching the meter, the FMO shall carefully "sweep" the area under measurement, carefully noting and recording all readings above ambient zero level. This is accomplished by the engineer by holding the instrument with its ion chamber facing the source to be measured. The instrument is slowly moved over the face of the cabinet or whatever container houses the suspected source. It must be done slowly because the meter is damped and there is a short delay time before the meter reaches its extremity value, up or down.

(7) Most likely areas of radiation will be around windows or door jambs of high power klystron or magnetron tube cabinets, such as those found in TACAN's and radars. Entire surfaces of cabinets, including the power supplies, should be systematically swept for readings. X-rays are generated by a stream of electrons impinging upon a metal surface under the influence of high voltages, usually in excess of 20 kilovolts.

(8) During the sweep, the instrument must be held well in front of the body, as it is moved toward or into the suspected field. To the extent possible, if less than PEL, put the sensor face as close to the device being measured as possible without touching it.

(9) Whenever a PEL is approached, the FMO will advance very slowly up to that limit. Should readings above the PEL be required, the instrument will be placed into those higher fields by means of a pole or other convenient device holding it, so the FMO is not subjected to levels above the PEL. At or above the PEL, the levels vs. distance in inches or feet from the radiating source are very important and should be measured and recorded for the report.

(10) Paragraph 1608 c. notwithstanding, if a level exceeding the PEL is found, the FMO shall advise the facility management that there may be a high level of radiation in the measured area, and personnel should avoid the area until competent medical personnel can evaluate the measurements. Further, the FMO will immediately telephone ASR and the Regional Medical Officer, even if after hours or a nonworkday.

(11) Instrument calibration should be accomplished at least annually, or at any time its accuracy is questioned.

1612. NON-IONIZED RADIATION MEASUREMENTS.

a. Non-ionized radiation refers to RF, even though it may be in the Extremely High Frequency (EHF) band, 30-300 GHz. Measurements of RF fields employ resonant loops (LF, MF, and HF), resonant dipoles (VHF and UHF), or isotropic probes for varied levels of high power in SHF and EHF. Measurements are made by FSM's, calibrated in mv/m or dB above 1 μv (dBmv) or power density meters calibrated in mW/cm^2. FSM's are typically used for lower level fields. Good treatises on this measurement theory are available in standard electronic engineering handbooks.

(1) The Narda power density meter is used for power levels of 1 mW/cm^2 and greater. The instrument consists of a hand-held calibrated detector circuit with an integral meter. Two associated probes for two different ranges of power have been supplied. One or the other of the probes is used, connected by the supplied cable to the detector. The Narda is usually used in connection with measurement of a high power radar or close proximity measurements of TACAN.

(a) First, the measuring engineer is to be thoroughly familiar with the instruction book for the instrument. Familiarity with operation procedures covered in the instruction book may be a matter of inquiry in any court testimony which could be required.

(b) The only calibration to be done is to check battery level and zero the instrument with appropriate probe attached. Proceed only if readings are normal. Note: The calibration/zero procedure is described in the instruction book. The probes need individual instrument insertion calibration for each use. The instruction book contains the procedure. Note that they are very delicate and must not only be handled with care, but not subjected to levels in excess of their ratings.

(c) Once calibrated, the measurement procedure may begin. Using the highest power probe, approach the source to be measured. If it is the radiation from the antenna of a rotating radar, prior arrangements will have to have been made to get radar shutdown so that a steady-state radiation can be obtained for measurement.

(d) All radar types currently used by FAA have been measured previously and found well below PEL below the antenna sail. Therefore, initial measurements can be started in the radome or at the pedestal level, so long as the engineer's body does not extend into the plane of the sail area. However, if there is any doubt whatsoever, measurements should be started well below the sail level and gradually moved up into the general area.

(e) The probes are nondirectional, except that a signal coming from the direction of the handle would not be measured accurately.

(f) To use the instrument, hold the detector in one hand, the probe in the other. Start well outside the expected area of high radiation. Slowly move into the area and "sweep" the suspect area with the probe pointed toward the source. "Toward" means that the probe handle is pointed away from the source. If the source is a radar, the radar antenna must be stopped, and the measurement location searchlighted, if the main beam of the radar is being investigated for radiation level. Hold the probe over the head at a reasonable distance. Using an elevating device such as a "cherry picker," the FMO should slowly move up into the main beam with the probe, while watching the Narda meter. Move the probe through the highest level of indicated radiation, until the level starts dropping.

(g) Once the PEL is reached, further intrusion beyond will be by remote means only. The Narda is supplied with a calibrated cable which is intended for this purpose. Use an appropriate non-metallic pole and fashion a lashing or mount for the probe. Using it at the end of the pole, slowly position the probe into the "hot" area being measured. All levels vs. distance must be accurately measured so that values of distance in feet and inches can be clearly shown on the report.

(h) If levels are found to be too low for the scale readings of the highest probe, the engineer should back off from the high density area, change and recalibrate with the lower power probe, then return to the area for measurement.

(i) For lower density devices, such as microwave ovens or microwave links, the process will be essentially the same, except the expected power levels will be so low that poles and other "remote reading" assisting devices will not be needed. If the level is below 1 mW/cm^2, then an FSM may be required, with appropriate antenna. Nonetheless, prudence shall be exercised in approaching the source to be measured.

1. If a microwave dish is the source, the probe can be slowly swept all over the face of the dish, even into the area of the feed horn. Since the average power is being measured from a pulsed source, the probe and associated equipment need a little time to come up to the correct reading. CAUTION: The probe surface must never touch any solid part of a device being measured. In some models, the contact can create an instantaneous static discharge which can destroy the delicate probe.

2. If a microwave oven or similar device is the source, the probe should be swept over the entire cabinet, with particular attention being given to the edges of the door, glass windows and vents. Again, it is imperative that the probe not touch the source.

(j) A chart of the distance vs. power density and PEL in the main beam of various radars now being used by FAA is found in Order 3910.3. The chart plus current additions is reproduced for convenience in figure 16-1.

(2) The field strength meters will be used for lower level measurement areas. The operation of the meters will be in the normal field strength measurement mode and procedure. The readings obtained will be in mv/m or dB/mv, and must be converted to power density from the formulas available in the Eaton instruction books. The conversion process is also covered in detail in the RFI manual referenced in paragraph 1400 of this order. But since the upper measurement limit of these instruments is well below the "safe" level, use normally will be at considerable distances from any high power source. Since they are capable of being operated on their internal batteries, they are amenable to use in portable conditions.

FIGURE 16-1. RADARS USED BY FAA WITH POWER DENSITIES >PEL

Radar Type	Transmitter Power Peak MW	Transmitter Power Average W	Nominal Frequency MHz	PEL mW/cm^2	Distance# Ft
AN/FPS-20	2.0	4319	1300	4.3	315
AN/FPS-60 (simplex)	2.0	4319	1300	4.3	315
AN/FPS-60 (duplex)	2.0	8638	1300	4.3	630
AN/FPS-6/90	2.8	2040	2800	5.0	360
ASDE	0.0045	3	15,950	5.0	*
ASR-4,-5,-6.	0.425	403	2800	5.0	40
ASR-7 (AN/GPN12)	0.5	475	2800	5.0	50
ASR-8 (AN/GPN-20/27) (Simplex)	1.4	875	2800	5.0	125
ASR-8 (AN/GPN-20/27) (Diplex)	1.4	1750	2800	5.0	235
ASR-9	1.237	1430	2800	5.0	280
ARSR-1,-2	5.0	3595	1315	4.4	295
ARSR-3 (simplex)	4.6	3140	1315	4.4	230
ARSR-3 (duplex)	4.6	6280	1315	4.4	460
ARSR-4	0.93	558	1315	4.4	260
NEXRAD (WSR-88)	1.0	2000	2850	5.0	234
TDWR	0.31	550	5625	5.0	500

* PEL not exceeded.

\# Calculated distance from antenna to point on main beam axis where power density equals the PEL.

1613. thru 1699. RESERVED.